

# **Investigation of Ground Water Contamination near Pavillion, Wyoming Phase V Sampling Event**

## **Summary of Methods and Results**

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# **Pavillion Phase V Sampling Event Summary of Methods and Results**

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## Executive Summary

The objective of the Phase V component of the Pavillion, Wyoming ground water investigation was to resample and reanalyze EPA's two deep monitoring wells (MW01 and MW02) in conjunction with the U.S. Geological Survey. The EPA also collected samples from five (5) domestic water wells located adjacent to the deep monitoring wells and a municipal well. Below, this "Summary of Methods and Results" details the methods, results, and QA/QC for the Phase V investigation.

### 1.0 Introduction

On December 8, 2011, the U.S. Environmental Protection Agency (EPA) released a draft report entitled *Investigation of Ground Water Contamination near Pavillion, Wyoming* (EPA, 2011) for public and peer review. This investigation was initiated in 2008 in response to complaints from several domestic well owners near the town of Pavillion, Wyoming regarding adverse changes in the quality of domestic well water. In response to these complaints, EPA initiated a ground water investigation in September 2008.

As described in the draft report, EPA conducted four sampling events (Phase I - IV): March 2009 (Phase I), January 2010 (Phase II), October 2010 (Phase III), and April 2011 (Phase IV). During these 4 phases, EPA collected ground water samples from 44 domestic wells, 4 stock wells, 2 municipal wells in the town of Pavillion, 3 shallow monitoring wells installed near drilling waste/wastewater pits with a Geoprobe, and two deep monitoring wells installed using air and mud rotary by EPA prior to the Phase III sampling event. During the Phase II sampling event, EPA also collected surface water and sediment samples from 5 locations along Five-Mile Creek (a creek traversing the area of investigation) and gas and produced water/condensate samples (organic compounds only) from 4 production wells. Results and associated quality assurance and quality control (QA/QC) of Phase I and II sampling events were summarized in EPA (2009) and EPA (2010), respectively. Results and associated quality assurance and quality control (QA/QC) of Phase III and IV sampling events and a summary of data from all phases was presented in EPA (2011). The draft report can be viewed at: <http://www.epa.gov/region8/superfund/wy/pavillion/>.

In early December, 2011, representatives from the United States Geological Survey (USGS), Wyoming State Geological Survey, Wyoming Department of Environmental Quality, Wyoming Oil and Gas Conservation Commission, and Wyoming Water Development Office met to discuss additional sampling of the two deep monitoring wells (MW01 and MW02) by USGS and EPA. In January 2012, EPA and USGS participated in technical discussions and correspondence related to development of USGS's draft Sampling and Analysis Plan (SAP) (USGS, 2012) for this sampling effort (which EPA refers to as Phase V). In order to be consistent with previous sampling and to continue to assess shallower ground water conditions, EPA also sampled five domestic wells, four of which were previously sampled, and one municipal well. A technical workgroup was formed consisting of personnel from EPA, USGS, the State of Wyoming, and the Northern Arapaho and Eastern Shoshone Tribes to develop purging and sampling approaches for EPA's two deep monitoring wells and to discuss differences in target analytes, analytical methods, and reporting limits for samples collected by EPA and USGS as outlined in EPA's Quality Assurance Project Plan (QAPP) (EPA, 2012) and the USGS Draft SAP (USGS, 2012).

Differences exist between EPA's QAPP and USGS's SAP, for example, in the analysis of samples for glycols and the sampling of low yield wells. EPA analyzed aqueous samples for glycols using high performance liquid chromatography-mass spectroscopy (HPLC-MS-MS) with a reporting limit of 10 µg/L. This low level glycol method has been developed by EPA and verified in multiple EPA laboratories. This new method will be submitted for publication in the peer reviewed literature. USGS utilized a commercial laboratory for glycol analysis using gas chromatography flame ionization detection (GC-FID) with a reporting limit of 25,000 µg/L.

During the Phase V sampling event, EPA purged and sampled five domestic wells and MW01 and MW02 (a low yield well). At MW01, EPA collected a series of ten sample sets during purging commencing at 1.44 borehole volumes and ending at 3.14 borehole volumes to evaluate concentration trends with purge volume. USGS collected two sample sets at MW01 at the beginning and end of EPA's sample sets. EPA collected two sample sets at MW02, which is a low yield well. The first sample set was collected at the initiation of purging. The second sample set was collected after removal of one borehole volume which required four purging events over a period of six days. EPA provided a sample set for analysis at the USGS contract laboratory during the second sampling event at MW02. EPA followed the Ground Water Sampling Guidance for Superfund and RCRA Project Managers (Yeskis and Zavala 2002) for sampling low yield wells.

Methods, results and associated analytical QA/QC for EPA's samples are provided in this results summary. USGS sampling and analytical methods used during the Phase V sample event are outlined in the USGS SAP (USGS, 2012). USGS sample results for MW02 are provided in Section C.

## **2.0 Methods**

EPA requires the use of a signed and approved QAPP prior to conducting a field or laboratory investigation. If sampling and/or analytical procedures change during multiple phases of a prolonged study, as is the case for this investigation, changes must be documented and approved in a revised version of the QAPP prior to implementation. Sampling and analytical procedures utilized by EPA during the Phase V sampling event are discussed in detail in the QAPP entitled "Ground Water Investigation in Pavillion, Wyoming, version 6" dated 2/17/2012 (EPA, 2012) and its Addendum version 1 dated 9/21/12.

Sampling conducted during the Phase V sampling event occurred between April 16 and April 24, 2012. EPA collected ground water samples from five domestic wells (PGDW05, PGDW20, PGDW23, PGDW30, and PGDW50), one municipal well (PGPW02), and two monitoring wells (MW01, and MW02). With the exception of PGDW50, each of these wells was sampled during previous events. PGDW50 is a stock well screened at a depth of 61 m (200 ft) bgs.

Field work was conducted pursuant to a signed and approved Health and Safety Plan (HASP). All personnel conducting sampling activities were required and had current HAZWOPER certification.

### **2.1 Institutional Purging Guidelines**

It is generally accepted that monitoring wells should be purged prior to sample collection (ASTM 2005, EPA 1986, USGS 2006), with one exception (Newell et al 2000). In a policy paper written for the American Petroleum Institute, Newell et al. (2000) cite a number of studies (e.g., Byrnes et al. 1996, Williams et al. 1996) indicating no statistical difference in pre- and post-purge concentrations of benzene, toluene, ethylbenzene, and xylene (BTEX) concentration.

The objective of purging in this investigation was to reduce the residence time of water in a well screen or casing to minimize the potential effect of negative and positive bias. Residence time is a function of well construction, vertical location of a pump within the casing, pumping rate, and permeability of the surrounding formation.

EPA's guidelines on purging to support investigations conducted under the Resource Conservation and Recovery Act (RCRA)(EPA 1986) and both RCRA and CERCLA (Yeskis and Zavala 2002) allow for considerable flexibility in purging strategies. USGS's national field manual requires purging prior to sample collection using specified "rules of thumb" (USGS, 2006). For this sampling event, USGS followed their national field manual (USGS, 2006).

## 2.2 Purging and Sampling Approach at Domestic Wells

A well volume approach combined with monitoring of stabilization parameters was used for purging domestic wells to maintain consistency with previous sampling events (EPA, 2009, 2010, 2011). For well PGDW05 a full purge of three casing volumes was not possible as the well ran dry before the purge could be completed (the well produced about 45 gallons of water before running dry). Well PGDW05 was sampled after pumping the well dry and allowing the well to recharge for 90 minutes.

Stabilization parameters such as temperature, specific conductance, oxidation-reduction potential, and pH were measured during the entire purge event. A portion of the flow was also diverted to a gas/water separator to monitor methane, carbon monoxide, hydrogen sulfide, and total hydrocarbons using portable flame- and photo-ionization detectors during the purging process.

Samples were collected as close to the ground water pump as possible. Samples were placed in coolers on ice, labeled, securely packed under chain of custody, and shipped to the various analytical laboratories.

## 2.3 Purging and Sampling Approach at MW01

EPA guidance on monitoring well purging is provided in EPA's Ground Water Sampling Guidelines for Superfund and RCRA Project Managers (Yeskis and Zavala 2002), which allows for considerable flexibility in use of purging strategies (depending on the setting, i.e., low flow, well volume, etc.). During the Phase IV sampling event (April 2011), wellbore modeling was used to determine the time or extraction volume at which stored casing water was replaced with formation water below the pump inlet (EPA 2011). This approach is based on the observation of little or no mixing in casing at the pump inlet upon stabilization of drawdown (Robins and Gillham 1987, Humenick et al. 1980). Upon stabilization of drawdown, all water flowing to a pump originates from the formation and flows vertically upward to the

pump. This enabled collection of samples of formation water from the immediate vicinity of the monitoring well thereby avoiding complexities associated with a large capture volume and associated concentration gradients within the aquifer. Wellbore modeling indicated that this occurred after removal of approximately one casing volume consistent with Humenick et al. (1980) for similarly designed deep monitoring wells.

A technical workgroup consisting of personnel from EPA, USGS, the State of Wyoming, and Tribal agencies was formed to develop consistent purging strategies at MW01 and MW02. After several detailed discussions to reconcile differences between EPA's wellbore mechanics approach and USGS's well volume approach to purging MW01, a consensus was reached within the technical workgroup to sample MW01 after removal of one borehole volume and upon stabilization of indicator water quality parameters. The State of Wyoming subsequently requested that USGS also collect a sample after purging at least three borehole volumes. Due to the potentially small geometry of the sand lens being sampled, EPA had concerns regarding potential oscillatory behavior and/or concentration change due to large volume water removal and the collection of samples radially and vertically farther out in the formation. This prompted EPA to conduct a time series analysis rather than relying on data collected at two endpoints. Therefore, EPA collected 10 samples between one and three borehole volumes.

Monitoring well MW01 was sampled by EPA and USGS on April 24, 2012. EPA collected its first sample at 1.44 borehole volumes and its first split sample with USGS occurred at 1.64 borehole volumes. EPA sample sets were collected at approximately 30 minute intervals. The timing of USGS's second and EPA's tenth sample coincided and occurred at 3.03 borehole volumes.

Discharge from MW01 was regulated using a 1" ball valve located between the pump discharge line (1" stainless steel pipe) and the sampling manifold. During initial well purging, all flow was diverted through an in-line, impeller flow meter, yielding instantaneous discharge rate (Q, in gallons per minute) and total volume (gallons). Time, instantaneous flow rate, total discharge volume, and drawdown in the well were recorded at regular intervals. Drawdown was measured using a sonic water level indicator. The bulk of flow was discharged to a waste tank and regulated using ½" gate valve. During sampling, a portion of the flow was diverted to: (1) an EPA flow cell, (2) a USGS flow cell, and (3) a gas/water separator to monitor methane, carbon monoxide, hydrogen sulfide, and total hydrocarbons using portable flame- and photo-ionization detectors. Water vigorously degassed during purging of MW01. Flow rates to the flow cells and the gas/water separator were adjusted as necessary using dedicated ½" ball valves.

#### 2.4 Purging and Sampling Approach at MW02

MW02 is a low-yield deep monitoring well. As discussed in the EPA draft report (EPA 2011), the reason for low yield at MW02 is uncertain. Gas intrusion during dewatering, potential isolation by shale of thin discontinuous sandstone lenses covering a portion of the screened interval, and/or insufficient removal of drilling mud during well development are several possible causes of low yield.

In its national field manual, USGS (2006) has a "rule of thumb" recommendation to avoid sampling a well that has not recovered to within 90% of its static water level within a 24-hour period and has had less than one borehole volume of water removed during purging. Based on this and because of the limited

time to develop alternative approaches, USGS elected not to sample MW02 during Phase V. However EPA collected samples for USGS at MW02 which were analyzed at a commercial laboratory under contract with USGS (Section C).

EPA guidance allows flexibility in sampling low yield monitoring wells to support investigations conducted under authority of RCRA and CERCLA. Under EPA guidelines, low yield neither constitutes a justification to preclude sampling nor a reason to disregard sample results from a monitoring well. EPA guidance on ground-water sampling for RCRA and CERCLA site managers indicates that a variety of methods can be employed to purge and sample slow-recovery wells (Yeskis and Zavala, 2002). Additional guidance on sampling low yield wells is provided in EPA's RCRA Ground-Water Monitoring Technical Enforcement Guidance document (EPA, 1986). This guidance recommends that low yield wells be evacuated to the practical extent possible (but not into the screened interval to avoid cascading of water) and subsequently sampled when sufficient water is present to support analysis. EPA (1986) also recommends that samples should then be collected in order of decreasing parameter volatility. These recommendations were followed at MW02 during the Phase V sampling event.

In the absence of significant exchange between a screened interval and a surrounding formation, increased retention time in a low yield well would be expected to result in loss of dissolved gases and volatile organic compounds (VOCs) from well casing (McAlary and Barker 1987) indicating a preference for sample collection after purging. However, dewatering a well having water with high total dissolved gas pressure results in bubble formation, gas flow in well casing, and stripping of dissolved gases and VOCs during the purging process itself (Roy and Ryan 2010), indicating a preference for sample collection prior to purging. During the Phase III and IV sampling events, purging at MW02 was interrupted by pump cavitation due to gas flow in well casing.

At MW02, samples were collected at the beginning and end of purging to compare concentrations of dissolved gases and VOCs in water in direct contact with the formation for a prolonged period of time (approximately 300 days) under high hydrostatic head with water entering the screened interval during purging under low hydrostatic head.

The purge and sample train for MW02 is similar to that utilized for MW01. In the purging and sampling sequence implemented in Phase V at MW02, the first set of samples was collected after removal of one submersible casing volume (165 liters or 43.7 gallons). MW02 was subsequently purged three more times within a six day period (6 days and 1 hour) to remove 1.04 borehole volumes (2012 liters or 532 gallons). Collection of the second sample set (EPAMW02-0412-2) occurred after 63 hours of recharge. Approximately 210 liters (55.6 gallons) of recharge occurred during this recharge period (0.06 LPM) equivalent to 1.1 screen (plus pre-packed screen and annular space between prepacked screen and borehole wall) exchanges. Samples were then collected after removal of 165 liters (43.6 gallons) of water in submersible pump casing. EPA collected a set of samples for analysis at USGS's laboratory at this time as well. This approach resulted in sampling water that represented a mixture of the oldest water originally present in casing near the atmospheric interface with water entering the well screen having a retention time of less than six days. Increased retention time increases the potential for loss of

light hydrocarbons, interaction with well construction materials, and biodegradation of organic compounds (Schilling 2011).

During the week of April 30th, 2012 (after cessation of Phase V sampling), a drilling crew from USGS removed the 3 HP submersible pump in MW02, examined the casing and screen with an optical televiewer, and attempted to redevelop the well. Suspended solids of unknown origin were observed, but no distinct visual evidence of cement intrusion was observed inside the stainless-steel screen with the optical televiewer. A member of the crew stated that tagging tape indicated that the base of the screen of MW02 was at 301.75 m (990') below ground surface (bgs) not 298.7 m (980') bgs as expected. The measuring tape was checked to ensure accuracy. However, the optical televiewer indicated that the well screen was close to the depth expected and consistent with the driller's logs. The optical televiewer indicated that the screen and casing were intact. Thus, the discrepancy in depth, if present, could not be caused by separation of the screen and casing. Redevelopment did not increase the rate of recharge.

During redevelopment, sediment was removed from the base of the screen. This material was placed in plastic baggies and returned to the ORD laboratory in Ada, OK. The material was dried and analyzed by powder x-ray diffraction techniques. Results indicate that the material is primarily composed of two iron oxides: magnetite and goethite (rather than bentonite as would be expected had mud intruded into the screen). Metals analyses were conducted.

## 2.5 Field Measurements during Well Sampling

Field measurements during the Phase V sampling event consisted of flow-cell readings for temperature, specific conductance, pH, oxidation-reduction potential, and dissolved oxygen. Electrodes were calibrated every morning of use. Performance checks were conducted at mid-day and at the end of each day. NIST-traceable 1413  $\mu\text{S}/\text{cm}$  specific conductance standard was used for calibration and performance checks. NIST-traceable buffer solutions (7.00 and 10.01) were used for pH calibration and performance checks. A pH 12.46 buffer solution was used as an electrode performance check prior to and after sampling the deep monitoring wells. An Oxidation-Reduction Potential (ORP) standard was used for calibration and performance checks of redox potential measurements. Dissolved oxygen sensors were calibrated with air, and low-oxygen measurement performance was tested with a zero-oxygen solution (sodium sulfite). Zero-oxygen solutions consistently read below 0.05 mg/L. Ground water was pumped through the flow cell at a rate between 0.9 and 1.6 L/min. Electrode readings were digitally logged every 2 minutes.

## 2.6 Sample Collection, Analysis, and Quality Assurance/Quality Control

Once flow-cell measurements stabilized (pH <0.02 units/min; specific conductance <1%/min; ORP <2 mV/min), ground water was collected into sample bottles as summarized in **Table B1 (Section B)**. Ground water samples were collected for a range of inorganic, organic, and stable isotope analyses. The samples were packed into ice chests loaded with bagged ice and shipped to receiving laboratories via overnight delivery. A 500 mL unfiltered sample was collected for field determinations of alkalinity, turbidity, ferrous iron, and dissolved sulfide. Alkalinity measurements were made in triplicate by incremental titration of ground water with sulfuric acid (EPA Method 310.1). Turbidity measurements



were made in triplicate with a portable meter (Hach 2100Q; EPA Method 180.1). Triplicate measurements were made for dissolved sulfide and ferrous iron using the methylene blue and 1,10-phenanthroline colorimetric methods, respectively (APHA, 1998a,b). Performance checks for measurements of alkalinity (100 mg/L, from sodium bicarbonate) and iron (1 mg/L, from HACH standard solution) were made in the field. Sample preservation and holding time criteria are listed in **Table B1 (Section B)**. Field quality control (QC) samples are summarized in **Table B2**. These included several types of blanks, duplicate samples, and field matrix-spike samples.

A total of 457 samples (not including duplicates of glass containers) were collected and delivered to 9 laboratories for analysis: Shaw Environmental, Ada, OK; EPA ORD/NRMRL, Ada, OK; ALS Environmental, Holland, MI; TestAmerica, Savannah, GA; EPA Region 8, Golden, CO; EPA Region 3, Fort Meade, MD; EPA ORD/NERL, Las Vegas, NV; Isotech, Champaigne, IL; and a Contract Laboratory Program laboratory for metals. Measurements were made for over 322 analytes per sample location. Of the 457 samples, 194 samples (42%) were QC samples, including blanks, field duplicates, matrix spikes, and matrix spike duplicates. Sampling and analytical procedures utilized by EPA during the Phase V sampling event are discussed in detail the Quality Assurance Project Plan (QAPP) entitled "*Ground Water Investigation in Pavillion, Wyoming, version 6*" (EPA, 2012) and its Addendum version 1 dated 9/21/12. The QAPP is available online at <http://www.epa.gov/region8/superfund/wy/pavillion/>.

Phase V QA/QC protocols are summarized in **Section B**. This appendix describes general QA practices and results of QC samples, including discussion of chain of custody, holding times, blank results, field duplicate results, laboratory Quality Assurance narratives, double-lab comparison of volatile organic compounds, Performance Evaluation samples, Quality Assurance Project Plan additions and deviations, field QC measurements, application of data qualifiers, and the Audit of Data Quality.

The software package AqQA (version 1.1.1) was used to evaluate internal consistency of water compositions by calculating cation/anion balances and by comparing measured and calculated electrical conductivity values. Geochemical equilibria in ground water were evaluated with the Geochemist's Workbench package (version 8; Bethke 1996). Speciation and mineral equilibria calculations were made by using temperature and concentrations of base species: major cations ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ), anions ( $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$ ), and pH. Activity corrections were made using the Debye-Hückel equation. The LLNL (EQ3/6) thermodynamic database was selected for use in the calculations (Delany and Lundeen 1990). Charge imbalance was handled by compensating with chloride for samples with an anion deficit or by compensating with sodium and separately with calcium for samples with a cation deficit.

## 3.0 Results

### 3.1 Domestic Wells

Five domestic wells (PGDW05, PGDW20, PGDW23, PGDW30, and PGDW50) and one municipal well (PGPW02) were sampled during Phase V. With the exception of PGDW50, each of these wells was sampled during previous events. Results from the Phase V sampling event are consistent with data

previously collected from these domestic wells. A comprehensive set of analytical results for the domestic wells sampled during the Phase V sampling event is located in Section A.

### 3.2 Deep Monitoring Well MW01

Methods for sampling MW01 were discussed in Sections 2.3. Results of the Phase V sampling event for MW01 are consistent with previous sampling events (see Table 1). A comprehensive set of Phase V analytical results for MW01 is located in Section A.

### 3.3 Deep Monitoring Well MW02

Methods for sampling MW02 are described in Section 2.4. Results of the Phase V sampling event for MW02 also are consistent with previous sampling events (see Table 2). A comprehensive set of analytical results for MW02 is located in Section A.

### 3.4 USGS MW02 Administrative Report

In December 2011, representatives from the United States Geological Survey (USGS) and the State of Wyoming began discussions to re-sample EPA's two deep monitoring wells (MW01 and MW02). EPA and USGS established a technical workgroup consisting of personnel from USGS, the EPA, the State of Wyoming, the Wind River Environmental Quality Commission, and the Northern Shoshone Business Council to discuss sampling approaches and analytical methods that would be employed by EPA and USGS. EPA and USGS sampling methods for MW01 are summarized in Section 2.3. EPA's Phase V results for MW01 are presented in **Section A**. USGS did not participate in sampling at MW02. EPA's methods for sampling MW02 are summarized in Section 2.4. EPA's Phase V results for MW02 are presented in **Section A**. USGS's Phase V analytical results for MW02 are attached.

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**Table 1.** Organic compounds in groundwater from MW01 (concentrations in µg/L)

Compound	Phase III Oct. 2010	Phase IV April 2011	Phase V April 2012 EPAMW01 0412-4	Phase V April 2012 EPAMW01 0412	Phase V April 2012 EPAMW01 0412-7	Phase V April 2012 EPAMW01 0412-10
Borehole Volumes		0.70	1.44 1.49	1.56 1.71	2.38 2.42	3.03 3.14
Methane	16000	17930	NM	17300	NM	18800
Ethane	2230	2950	NM	2380	NM	2270
Propane	790	1250	NM	763	NM	715
Dissolved Organic Carbon	8510	9430	NM	5630	NM	3360
Diesel Range Organics	634	924	555	484	379	267
Gasoline Range Organics	389	592	584	528	418	328
<i>BTEX</i>						
Toluene (Shaw)	NM	0.59	<0.50 (U)	<0.50 (U)	<0.50 (U)	<0.50 (U)
Toluene (R8)	0.75	0.56 (J)	NM	<0.25 (U)	NM	<0.25 (U)
<i>Alcohols</i>						
Isopropanol	NM	212	65.0 (J)	69.8 (J)	62.6 (J)	69.3 (J)
Tert butyl Alcohol	NM	<5.0 (U)	<5.0 (U)	<5.0 (U)	<5.0 (U)	<5.0 (U)
<i>Ketones</i>						
Acetone (R8)	NM	79.5 (H, J)	NM	155 (J)	NM	114 (J)
Acetone (Shaw)	NM	NM	<5 (U)	<5 (U)	<5 (U)	<5 (U)
4 Methyl 2 Pentanone	NM	2.60 (H, J)	NM	1.39 (J)	NM	0.59 (J)
2 Hexanone	NM	0.37 (H, J)	NM	0.26 (J)	NM	<0.25 (U)
<i>Semi Volatiles</i>						
Phenol	10.7	19.0	9.65	8.09 (J+)	6.68	5.42
Benzoic Acid	212	457 (J)	735 (*, J)	221 (*)	310 (*)	237 (*)
<i>Glycols by HPLC MS MS</i>						
Diethylene Glycol	NM	226 (J)	60.0 (J)	53.9 (J)	34.1 (J)	26.4 (J)
Triethylene Glycol	NM	46 (J)	12.7 (J)	11.5 (J)	4.9 (J)	2.9 (J)
Tetraethylene Glycol	NM	7.3 (J, B)	<10 (J, U)	<10 (J, U)	<10 (J, U)	<10 (J, U)
2 Butoxyethanol (R3)	NM	<10 (U)	5.1 (J)	3.5 (J)	1.5 (J)	<5 (J, U)
2 Butoxyethanol (R8, SVOC)	<0.25 (U)	12.7	<1.0 (U)	5.78†	3.49	<1.0 (U)
<i>Surfactants</i>						
MBAS††	NM	NM	<200 (U)	<200 (U)	<200 (U)	<200 (U)
Nonylphenol	NM	NM	0.65 (J, B)	0.60 (J, B)	0.65 (J, B)	0.24 (J, B)
Octylphenol	NM	NM	0.16 (J)	0.14 (J)	0.10 (J)	0.05 (J)
Acetate	NM	8050	NM	3420 (*)	NM	6080

NM – not measured. See Section A for a list of data qualifiers. †The concentration of 2-butoxyethanol reported is from the field duplicate; analyte was undetected in the primary sample. ††MBAS is methylene blue active substances. Data for diethylene glycol, triethylene glycol, tetraethylene glycol, 2-butoxyethanol (R3), nonylphenol, and octylphenol are all qualified as estimated because the methods used for analysis are under development.

Table 2. Organic compounds in groundwater from MW02 (concentrations in µg/L).					
Compound	(Oct. 2010) Phase III	(April 2011) Phase IV	April (2012) EPAMW02 0412-1 No Purge Sample	(April 2012) EPAMW02 0412-2 1 borehole volume sample	(April 2012) EPAMW02 0412-2 USGS spilt - 1 borehole volume sample
Methane	18990	18820	19100	22000	32000
Ethane	3290	2550	3060	3070	4900
Propane	1820	2260	1580	1780	2200
Dissolved Organic Carbon	14500	19700	19400	15500	13000
Diesel Range Organics	1440 (J)	4050	4150	2100	670
Gasoline Range Organics	3710	2800	4500	5290	6800
<b>BTEX</b>					
Benzene	246	183	166	232	250
Toluene	617	482	402	607	690
Ethylbenzene	67.0	68.7	61.1	101	100
Xylenes	750	805	710	1139	1260
Trimethylbenzenes	105	157	142	254	271
<b>Alcohols</b>					
Isopropanol	NM	581	862	802	<800 (U)
Tert butyl Alcohol	NM	4470	5910	6120	6300
<b>Ketones</b>					
Acetone	NM	641 (H)	982 (J)	157 (J)	350
2-Butanone	NM	120 (H)	208 (J)	86.2 (J)	<120 (U)
<b>Semi-Volatiles</b>					
Phenols	82.3	64.9	131.3 (J)	102.3	156
Naphthalenes	3.22	6.10	10.6	13.2	17.4 (J)
Bis(2-ethylhexyl)phthalate	6.76	2.17	3.52 (J)	2.10	3.6
Benzoic Acid	244	209 (J)	513	110 (*)	38 TIC (J)
<b>Glycols by HPLC-MS/MS</b>					
Diethylene Glycol	NM	1570 (J)	1260 (J)	378 (J)	<25000 (U)
Triethylene Glycol	NM	310 (J)	262 (J)	72.3 (J)	<25000 (U)
Tetraethylene Glycol	NM	27.2 (J, B)	22.6 (J)	3.6 (J)	NM
2-Butoxyethanol	NM	<10.0 (U)	6.8 (J)	<5.0 (U)	TIC
<b>Surfactants</b>					
Nonylphenol	NM	NM	28 (H, J)	7.4-7.9 (J)	NM
Octylphenol	NM	NM	2.9 (H, J)	0.5-0.7 (J)	NM
MBAS	NM	NM	<0.20 (U)	<0.20 (U)	0.12 (J)
Acetate	NM	4310	4800	2840 (J)	NM

Table Notes: NM – not measured. TIC – tentatively identified compound. See Section A for list of data qualifiers. BTEX compounds for Phase IV and V are from EPA Method 5021A plus 8260C; for Phase III EPA Method 5035 plus 8260C was used. A comparison between the two methods for Phase V spilt samples is presented in Section B. Xylenes = o-xylene + m+p-xylene. Trimethylbenzenes in Phase IV and Phase V = 1,3,5-trimethylbenzene + 1,2,4-trimethylbenzene + 1,2,3-trimethylbenzene. Trimethylbenzenes in Phase III = 1,3,5-trimethylbenzene + 1,2,4-trimethylbenzene. Alcohols determined by EPA Method 5021A plus 8260C. Ketones determined by Method 5035 plus 8260C. Semi-volatile organic compounds determined by EPA Method 8270D. Naphthalenes = 1-methylnaphthalene+2-methylnaphthalene+naphthalene. Phenols = phenol +2,4-dimethylphenol + 2-methylphenol + 3&4-methylphenol. MBAS is methylene blue active substances. Glycols analysis was performed by modifying ASTM D 7731-11 and using EPA SW-846 Methods 8000C and 8321 to allow performance at lower detection limits. Sample results for diethylene glycol, triethylene glycol, tetraethylene glycol, 2-butoxyethanol (R3), are all qualified as estimated because the method is still under development. Nonylphenol and octylphenol analysis followed ASTM D 7485-09 and USGS Method O-1433-01, and are qualified as estimated because the methods are still under development. Acetate determined by HPLC (RSKSOP-112v6).